CHAPTER 1

Systems of Measurement

1* · Which of the following is *not* one of the fundamental physical quantities in the SI system?
(*a*) mass (*b*) length (*c*) force (*d*) time (*e*) All of the above are fundamental physical quantities.
(*c*) Force is *not* a fundamental physical quantity; see text.

2 · In doing a calculation, you end up with m/s in the numerator and m/s^2 in the denominator. What are your final units? (*a*) m^2/s^3 (*b*) 1/s (*c*) s^3/m^2 (*d*) s (*e*) m/s
(*d*) (m/s)/(m/s^2) = (m/s)(s^2/m) = s.

3 · Write the following using prefixes listed in Table 1-1 and the abbreviations listed on page EP-1; for example, 10,000 meters = 10 km. (*a*) 1,000,000 watts, (*b*) 0.002 gram, (*c*) 3×10^{-6} meter, (*d*) 30,000 seconds.
(*a*) 1 MW (*b*) 2 mg (*c*) 3 μm (*d*) 30 ks

4 · Write each of the following without using prefixes: (*a*) 40 μW, (*b*) 4 ns, (*c*) 3 MW, (*d*) 25 km.
(*a*) 0.000040 W (*b*) 0.000000004 s (*c*) 3,000,000 W (*d*) 25,000 m

5* · Write out the following (which are not SI units) wihout using any abbreviations. For example, 10^3 meters = 1 kilometer. (*a*) 10^{-12} boo, (*b*) 10^9 low, (*c*) 10^{-6} phone, (*d*) 10^{-18} boy, (*e*) 10^6 phone, (*f*) 10^{-9} goat (*g*) 10^{12} bull.
(*a*) 1 picoboo (*b*) 1 gigalow (*c*) 1 microphone (*d*) 1 attoboy (*e*) 1 megaphone (*f*) 1 nanogoat (*g*) 1 terabull

6 ·· In the following equations, the distance *x* is in meters, the time *t* is in seconds, and the velocity *v* is in meters per second. What are the SI units of the constants C_1 and C_2? (*a*) $x = C_1 + C_2t$ (*b*) $x = 1/2C_1t^2$ (*c*) $v^2 = 2C_1x$
(*d*) $x = C_1 \cos C_2t$ (*e*) $v = C_1 e^{-C_2t}$

(*a*) C_1 and C_2t must be in meters	C_1 in m; C_2 in m/s
(*b*) C_1t^2 must be in meters	C_1 in m/s^2
(*c*) v^2 is in m^2/s^2; so C_1x must be in m^2/s^2	C_1 in m/s^2

(d) cos C_2t is a number; C_2t is a number — C_1 in m; C_2 in s^{-1}

(e) v is in m/s. C_2t is a number — C_1 in m/s; C_2 in s^{-1}

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7 ·· If x is in feet, t is in seconds, and v is in feet per second, what are the units of the constants C_1 and C_2 in each part of Problem 6?

It is only necessary to change the unit of length in each case from m (meter) to ft (foot). Thus, for example, in part (e), we have C_1 in ft/s; C_2 in s^{-1}.

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8 · From the original definition of the meter in terms of the distance from the equator to the North Pole, find in meters (a) the circumference of the earth, and (b) the radius of the earth. (c) Convert your answers for (a) and (b) from meters into miles.

(a) The Pole–Equator distance is one-fourth of the circumference — $C = 4 \times 10^7$ m

(b) Use $C = 2\pi R$ — $R = (4 \times 10^7\ \text{m})/2\pi = 6.37 \times 10^6$ m

(c) Use the conversion factor (1 mi)/(1.61 km) = 1 — $C = (4 \times 10^7\ \text{m})(1\ \text{mi}/1.61 \times 10^3\ \text{m}) = 2.46 \times 10^4$ mi

$R = (6.37 \times 10^6\ \text{m})(1\ \text{mi}/1.61 \times 10^3\ \text{m}) = 3.96 \times 10^3$ mi

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9* · The speed of sound in air is 340 m/s. What is the speed of a supersonic plane that travels at twice the speed of sound? Give your answer in kilometers per hour and miles per hour.

1. Find the speed in m/s — v = 2(340 m/s) = 680 m/s = 0.680 km/s
2. Use [1 h/(60 min/h)(60 s/min)] = 1 — v = (0.680 km/s)/(1 h/3600 s/h) = 2450 km/h
3. Use (1 mi/1.61 km) = 1 — v = (2450 km/h)(1 mi/1.61 km) = 1520 mi/h

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10 · A basketball player is 6 ft $10\frac{1}{2}$ in tall. What is his height in centimeters?

1. Express H in inches — $H = (6 \times 12 + 10.5)$ in = 82.5 in
2. Use (1 in/2.54 cm) = 1 — H = (82.5 in)/(1 in/2.54 cm) = 210 cm

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11 · Complete the following: (a) 100 km/h = ___mi/h; (b) 60 cm = ___in; (c) 100 yd = ___m.

(a) (100 km/h)(1 mi/1.61 km) = 62.1 mi/h; (b) (60 cm)(1 in/2.54 cm) = 23.6 in;

(c) (100 yd)/(1 yd/0.9144 m) = 91.4 m.

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12 · The main span of the Golden Gate Bridge is 4200 feet. Express this distance in kilometers.

(4200 ft)/(1 ft/0.3048 m)(1000 m/1 km) = 1.28 km.

13* · Find the conversion factor to convert from miles per hour into kilometers per hour.

Since 1 mi = 1.61 km, (v mi/h) = (v mi/h)(1.61 km/1 mi) = 1.61v km/h.

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14 · Complete the following: (a) 1.296×10^5 km/h^2 =___ km/h s; (b) 1.296×10^5 km/h^2 = ___m/s^2; (c) 60 mi/h = ___ft/s; (d) 60 mi/h = ___m/s.

(a) (1.296×10^5 km/h^2)(1 h/3600 s) = 36.00 km/h·s; (b) (36.00 km/h·s)(1 h/3600 s)(1000 m/1 km) = 10 m/s^2;

(c) (60 mi/h)(5280 ft/1 mi)(1 h/3600 s) = 88 ft/s; (d) (88 ft/s)(0.3048 m/1 ft) = 27 m/s.

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15 · There are 1.057 quarts in a liter and 4 quarts in a gallon. (a) How many liters are there in a gallon? (b) A barrel equals 42 gallons. How many cubic meters are there in a barrel?

(a) 1 gal = (1 gal)(4 qt/1 gal)(1 L/1.057 qt) = 3.784 L;
(b) 1 ba = (1 ba)(42 ga/1 ba)(3.784 L/1 ga)(1 m^3/1000 L) = 0.1589 m^3.

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16 · There are 640 acres in a square mile. How many square meters are there in one acre?
1 acre = (1 acre)(1 mi^2/640 acres)(1610 m/1 mi)^2 = 4050 m^2.

17* ·· A right circular cylinder has a diameter of 6.8 in and a height of 2 ft. What is the volume of the cylinder in (a) cubic feet, (b) cubic meters, (c) liters?

(a) 1. Express the diameter in feet — D = (6.8 in)(1 ft/12 in) = 0.567 ft
2. The volume of a cylinder is $V = (\pi D^2/4)H$ — $V = [\pi(0.567\text{ ft})^2/4](2\text{ ft}) = 0.505\text{ ft}^3$
(b) Use (1 ft/0.3048 m) = 1 — $V = (0.505\text{ ft}^3)(0.3048\text{ m/1 ft})^3 = 0.0143\text{ m}^3$
(c) Use (1000 L/1 m^3) = 1 — $V = (0.0143\text{ m}^3)(1000\text{ L/1 m}^3) = 14.3\text{ L}$

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18 ·· In the following, x is in meters, t is in seconds, v is in meters per second, and the acceleration a is in meters per second squared. Find the SI units of each combination: (a) v^2/x; (b) $\sqrt{x/a}$; (c) $\frac{1}{2}at^2$.

(a) The units of v^2/x are (m^2/s^2)/m = m/s^2; (b) the units of $\sqrt{x/a}$ are [m/(m/s^2)]$^{1/2}$ = s;
(c) the units of $\frac{1}{2}at^2$ are (m/s^2)s^2 = m.

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19 · What are the dimensions of the constants in each part of Problem 6?
Referring to the results of Problem 6 we see that the dimensions are:
(a) $C_1 : L$, $C_2 : L/T$; (b) $C_1 : L/T^2$; (c) $C_1 : L/T^2$; (d) $C_1 : L$, $C_2 : 1/T$; (e) $C_1 : L/T$, $C_2 : 1/T$.

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20 ·· The law of radioactive decay is $N(t) = N_0e^{-\lambda t}$, where N_0 is the number of radioactive nuclei at t = 0, $N(t)$ is the number remaining at time t, and λ is a quantity known as the decay constant. What is the dimension of λ?

Since the exponent must be a number, the dimension of λ must be $1/T$.

21* ·· The SI unit of force, the kilogram-meter per second squared (kg m/s^2) is called the newton (N). Find the dimensions and the SI units of the constant G in Newton's law of gravitation $F = Gm_1m_2/r^2$.

1. Solve for G — $G = Fr^2/m_1m_2$
2. Replace the variables by their dimensions — $G = (ML/T^2)(L^2)/(M^2) = L^3/(MT^2)$
3. Use the SI units for L, M, and T — Units of G are m^3/kg s^2

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22 ·· An object on the end of a string moves in a circle. The force exerted by the string has units of ML/T^2 and
depends on the mass of the object, its speed, and the radius of the circle. What combination of these variables gives the correct dimensions?

1. Write the relationship in terms of powers of the variables — $F = m^av^br^c$
2. Insert the appropriate dimensions — $MLT^{-2} = M^a(L/T)^bL^c$
3. Solve for the exponents a, b, and c — $a = 1$; $b = 2$; $b + c = 1$, $c = -1$
4. Write the corresponding expression — $F = mv^2/r$

23 ·· Show that the product of mass, acceleration, and speed has the dimension of power.

1. Write the dimensions of the variables $m : M,\ a : L/T^2,\ v : L/T,\ P : ML^2/T^3$
2. Find the dimensions of the product $mav : M(L/T^2)(L/T) = ML^2/T^3 : P$

mav

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24 ·· The momentum of an object is the product of its velocity and mass. Show that momentum has the dimension of force multiplied by time.

The dimension of mv is ML/T; the dimension of force times time is $(ML/T^2)(T) = ML/T$.

25* ·· What combination of force and one other physical quantity has the dimension of power?

(ML/T^2)(dimension of Y) $= ML^2/T^3$; dimension of Y $= (ML^2/T^3)/(ML/T^2) = L/T$; Y = velocity.

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26 ·· When an object falls through air, there is a drag force that depends on the product of the surface area of the

object and the square of its velocity, i.e., $F_{air} = CAv^2$, where C is a constant. Determine the dimension of C.

1. Solve for the constant C $C = F_{air}/Av^2$
2. Replace the variables by their $C = (ML/T^2)/[L^2(L/T)^2] = M/L^3$

dimensions

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27 ·· Kepler's third law relates the period of a planet to its radius r, the constant G in Newton's law of gravitation $(F = Gm_1m_2/r^2)$, and the mass of the sun M_S. What combination of these factors gives the correct dimensions for the period of a planet?

1. Write a general expression for the period in terms of the dimensions of the variables $T = L^aG^bM^c$; note that $G = L^3/(MT^2)$ (see Problem 21) $T = L^a[L^3/(MT^2)]^bM^c = L^{a+3b}M^{c-b}T^{-2b}$
2. Solve for b, c, and a in that order $-2b = 1,\ b = -1/2;\ c - b = 0,\ c = -1/2;\ a + 3b = 0,\ a = 3/2$
3. Write the result in terms of r, G, and M_S $T = C(r^{3/2})/\sqrt{M_S G}$, where C is a numerical constant.

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28 · The prefix giga means ____. (*a*) 10^3 (*b*) 10^6 (*c*) 10^9 (*d*) 10^{12} (*e*) 10^{15}

(*c*) 10^9; see Table 1-1.

29* · The prefix mega means ____. (*a*) 10^{-9} (*b*) 10^{-6} (*c*) 10^{-3} (*d*) 10^6 (*e*) 10^9

(*d*) 10^6; see Table 1-1.

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30 · The prefix pico means ____. (*a*) 10^{-12} (*b*) 10^{-6} (*c*) 10^{-3} (*d*) 10^6 (*e*) 10^9

(*a*) 10^{-12}; see Table 1-1.

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31 · The number 0.0005130 has ____ significant figures. (*a*) one (*b*) three (*c*) four (*d*) seven (*e*) eight

(*c*) four; the three zeros after the decimal point are not significant figures, but the last zero is significant.

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32 · The number 23.0040 has ____ significant figures. (*a*) two (*b*) three (*c*) four (*d*) five (*e*) six

(*e*) six; all digits including the last zero are significant.

33* · Express as a decimal number without using powers of 10 notation: (*a*) 3×10^4 (*b*) 6.2×10^{-3} (*c*) 4×10^{-6} (*d*) 2.17×10^5

(a) $3 \times 10^4 = 30{,}000$; (b) $6.2 \times 10^{-3} = 0.0062$; ($c$) $4 \times 10^{-6} = 0.000004$; ($d$) $2.17 \times 10^5 = 217{,}000$.

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34 · Write the following in scientific notation. (a) 3.1 GW = ____W. (b) 10 pm = ____m. (c) 2.3 fs = ____s.
(d) 4 μs = ____s.

(a) 3.1 GW = 3.1×10^9 W; (b) 10 pm = 10^{-11} m; (c) 2.3 fs = 2.3×10^{-15} s; (d) 4 μs = 4×10^{-6} s.

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35 · Calculate the following, round off to the correct number of significant figures, and express your result in scientific notation. (a) $(1.14)(9.99 \times 10^4)$ (b) $(2.78 \times 10^{-8}) - (5.31 \times 10^{-9})$ (c) $12\pi/(4.56 \times 10^{-3})$
(d) $27.6 + (5.99 \times 10^2)$

(a) The number of significant figures in each factor is three, so the result has three significant figures — $(1.14)(9.99 \times 10^4) = 11.4 \times 10^4 = 1.14 \times 10^5$

(b) We must first express both terms with the same power of ten. Since the first number has only two digits after the decimal point, the result can have only two digits after the decimal point. — $(2.78 \times 10^{-8}) - (5.39 \times 10^{-9}) = (2.78 - 0.539) \times 1$
$(2.78 \times 10^{-8}) - (5.39 \times 10^{-9}) = 2.24 \times 10^{-8}$

(b) We assume here that 12 is an exact number. Hence the answer has three significant figures. — $12\pi/(4.56 \times 10^{-3}) = 8.27 \times 10^3$

(d) See (b) above — $27.6 + 599 = 627 = 6.27 \times 10^2$

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36 · Calculate the following, round off to the correct number of significant figures, and express your result in scientific notation. (a) $(200.9)(569.3)$ (b) $(0.000000513)(62.3 \times 10^7)$ (c) $28401 + (5.78 \times 10^4)$
(d) $63.25 / (4.17 \times 10^{-3})$

(a) Both factors have 4 significant figures — $(200.9)(569.3) = 1.144 \times 10^4$

(b) Express the first factor in scientific notation. — $0.000000513 = 5.13 \times 10^{-7}$
Both factors have 3 significant figures. — $(5.13 \times 10^{-7})(62.3 \times 10^7) = 3.20 \times 10^2$

(c) Express both terms in scientific notation; the second term and result have only 3 significant figures — $28{,}401 = 2.8401 \times 10^4$
$2.8401 \times 10^4 + 5.78 \times 10^4 = 8.62 \times 10^4$

(d) The result has 3 significant figures — $63.25/(4.17 \times 10^{-3}) = 1.52 \times 10^4$

37* · A cell membrane has a thickness of about 7 nm. How many cell membranes would it take to make a stack
1 in high?

1. The number of membranes is the total thickness divided by the thickness per membrane — $N = (1 \text{ in})/(7 \times 10^{-9} \text{ m/membrane})$
2. Use all SI units — $N = (1 \text{ in})(2.54 \times 10^{-2} \text{ m/1 in})/(7 \times 10^{-9} \text{ m/membrane})$
3. Solve for N; give result to 1 significant figure — $N = 4 \times 10^6$ membranes

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38 · Calculate the following, round off to the correct number of significant figures, and express your result in scientific notation. (a) $(2.00 \times 10^4)(6.10 \times 10^{-2})$ (b) $(3.141592)(4.00 \times 10^5)$ (c) $(2.32 \times 10^3)/(1.16 \times 10^8)$ (d) $(5.14 \times 10^3) + (2.78 \times 10^2)$; ($e$) $(1.99 \times 10^2) + (9.99 \times 10^{-5}$

(a) Both factors, and hence result, have 3 sig. figs. — $(2.00 \times 10^4)(6.10 \times 10^{-2}) = 1.22 \times 10^3$
$(3.141592)(4.00 \times 10^5) = 1.26 \times 10^6$

(*b*) The 2nd factor, and hence the result, has 3 sig. figs. $(2.32 \times 10^3)/(1.16 \times 10^8) = 2.00 \times 10^{-5}$

(*c*) See (*a*) $(5.14 \times 10^3) + (2.78 \times 10^2) = (5.14 \times 10^3) + (0.278 \times 10^3) = (5.14 + 0.278) \times 10^3 = 5.42 \times 10^3$

(*d*) Write both terms using same power of 10; note that result has only 3 sig. figs. $(1.99 \times 10^2) + (0.000000999 \times 10^2) = 1.99 \times 10^2$

(*e*) Follow procedure as in (*d*)

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39 · Perform the following calculations and round off the answers to the correct number of significant figures:

(*a*) $3.141592654 \times (23.2)^2$ (*b*) $2 \times 3.141592654 \times 0.76$ (*c*) $(4/3)\pi \times (1.1)^3$ (*d*) $(2.0)^5/3.141592654$

Note that 3.141592654 is π to 10 significant figures.

(*a*) The second factor and result have 3 sig. figs. $(23.2)^2\pi = 1.69 \times 10^3$

(*b*) We assume 2 is exact; result has 2 sig. figs. $2\pi \times 0.76 = 4.8$

(*c*) Again, (4/3) is assumed exact; 2 sig. figs. $(4/3)\pi \times (1.1)^3 = 5.6$

(*d*) 2.0 has 2 sig. figs., so result has 2 sig. figs. 10

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40 ·· The sun has a mass of 1.99×10^{30} kg and is composed mostly of hydrogen, with only a small fraction being heavier elements. The hydrogen atom has a mass of 1.67×10^{-27} kg. Estimate the number of hydrogen atoms in the sun.

1. Assume the sun is made up only of hydrogen $M_S = N_H M_H$, where N_H is number of H atoms
2. Solve for N_H $N_H = M_S/M_H = 1.99 \times 10^{30}/(1.67 \times 10^{-27}) = 1.19 \times 10^{57}$

41* · What are the advantages and disadvantages of using the length of your arm for a standard length?

The advantage is that the length measure is always with you. The disadvantage is that arm lengths are not uniform, so if you wish to purchase a board of “two arm lengths” it may be longer or shorter than you wish, or else you may have to physically go to the lumber yard to use your own arm as a measure of length.

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42 · A certain clock is known to be consistently 10% fast compared with the standard cesium clock. A second clock varies in a random way by 1%. Which clock would make a more useful secondary standard for a laboratory? Why?

The first clock is a better secondary standard because one can make a precise correction for the discrepancy between it and the cesium standard.

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43 · True or false:

(*a*) Two quantities to be added must have the same dimensions.

(*b*) Two quantities to be multiplied must have the same dimensions.

(*c*) All conversion factors have the value 1.

(*a*) True; you cannot add “apples to oranges” or a length (distance traveled) to a volume (liters of milk).

(*b*) False; the distance traveled is the product of speed (length/time) multiplied by the time of travel (time).

(*c*) True; see text.

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44 · On many of the roads in Canada the speed limit is 100 km/h. What is the speed limit in miles per hour?

(100 km/h)(1 mi/1.61 km) = 62 mi/h.

45* · If one could count $1 per second, how many years would it take to count 1 billion dollars (1 billion = 10^9)?

It would take 10^9 seconds or (10^9 s)(1 h/3600 s)(1 day/24 h)(1 y/365 days) = (10^9 s)(1 y/3.154 × 10^7 s) = 31.7 y.

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46 · Sometimes a conversion factor can be derived from the knowledge of a constant in two different systems. (*a*) The speed of light in vacuum is 186,000 mi/s = 3 × 10^8 m/s. Use this fact to find the number of kilometers in a mile. (*b*) The weight of 1 ft^3 of water is 62.4 lb. Use this and the fact that 1 cm^3 of water has a mass of 1 g to find the weight in pounds of a 1-kg mass.

(*a*) From the data, (3.00 × 10^8 m/s)/(1.86 × 10^5 mi/s) = 1 = 1.61 × 10^3 m/mi = 1.61 km/mi.

(*b*) 1. Find the volume of 1.00 kg of water	Volume of 1.00 kg = 10^3 g is 10^3 cm^3
2. Express 10^3 cm^3 in ft^3	$(10\text{ cm})^3[(1\text{ in}/2.54\text{ cm})(1\text{ ft}/12\text{ in})]^3 = 0.0353\text{ ft}^3$
3. So (1.00 kg/0.0353 ft^3) = (62.4 lb/1 ft^3)	(62.4 lb/1 ft^3)/(1.00 kg/0.0353 ft^3) = 2.20 lb/kg

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47 ·· The mass of one uranium atom is 4.0 × 10^{-26} kg. How many uranium atoms are there in 8 g of pure uranium? N_U = (8.0 g)(1 U/4.0 × 10^{-26} kg)(10^{-3} kg/1 g) = 2.0 × 10^{23}.

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48 ·· During a thunderstorm, a total of 1.4 in of rain falls. How much water falls on one acre of land? (1 mi^2 =
640 acres.)

1. Express the area in ft^2	(1 acre) (1 mi^2/640 acre)$(5280\text{ ft}/1\text{ mi})^2$ = 4.356 × 10^4 ft^2
2. Find the total volume of water on 1 acre in cubic feet.	V = (4.356 × 10^4 ft^2)(1.4 in)(1 ft/12 in) = 5.08 × 10^3 ft^3
3. Use the fact that 1ft^3 of water weighs 62.4 lb	Weight of water = (62.4 lb/ft^3)(5.08 × 10^3 ft^3) = 3.17 × 10^5 lb

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49* ·· The angle subtended by the moon's diameter at a point on the earth is about 0.524°. Use this and the fact that the moon is about 384 Mm away to find the diameter of the moon. (The angle subtended by the moon θ is approximately D/r_m, where D is the diameter of the moon and r_m is the distance to the moon.)

Note that $\theta \approx D/r_m$ for small values of θ only if θ is expressed in radians, and that radians are dimensionless.

1. Find θ in radians	(0.524 deg)(2π rad/360 deg) = 0.00915 rad
2. Use $\theta = D/r_m$ and solve for D	$D = \theta r_m$ = (0.00915)(384 Mm) = 3.51 Mm

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50 ·· The United States imports 6 million barrels of oil per day. This imported oil provides about one-fourth of our total energy. A barrel fills a drum that stands about 1 m high. (*a*) If the barrels are laid end to end, what is the length in kilometers of barrels of oil imported each day? (*b*) The largest tankers hold about a quarter-million barrels. How many tanker loads per year would supply our imported oil? (*c*) If oil costs $20 a barrel, how much do we spend for oil each year?

(*a*) L = (6 × 10^6 barrels)(1 m/1 barrel) = 6 × 10^6 m = 6 × 10^3 km.

(*b*) Number of tankers per year = (6 × 10^6 barrels/1 day)(365 day/1 y)(1 tanker/0.25 × 10^6 barrels) = 8.76 × 10^3 tankers.

(b) Cost per year = (6 × 10^6 barrels/1 day)(365 days/1 y)($20/barrel) = $4.38 × 10^{10} = $43.8 billion.

51 ·· Every year the United States generates 160 million tons of municipal solid waste and a grand total of 10
billion tons of solid waste of all kinds. If one allows one cubic meter of volume per ton, how many square miles of area at an average height of 10 m is needed for landfill each year?

1. Find the total volume of landfill needed — $V = (10 \times 10^9 \text{ tons})(1 \text{ m}^3/1 \text{ ton}) = 10^{10} \text{ m}^3$
2. Find the surface area needed using $V = AH$ — $A = V/H = (10^{10} \text{ m}^3)/(10 \text{ m}) = 10^9 \text{ m}^2$
3. Express A in mi^2 — $A = (10^9 \text{ m}^2)(1 \text{ mi}/1610 \text{ m})^2 = 3.86 \times 10^2 \text{ mi}^2$

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52 ·· An iron nucleus has a radius of 5.4×10^{-15} m and a mass of 9.3×10^{-26} kg. (*a*) What is its mass per unit volume in kg/m^3? (*b*) If the earth had the same mass per unit volume, what would its radius be? (The mass
of the earth is 5.98×10^{24} kg.)

(*a*) 1. Find the volume of an iron nucleus — $V = (4/3)\pi r^3 = (4/3)\pi(5.4 \times 10^{-15} \text{ m})^3 = 6.6 \times 10^{-43} \text{ m}^3$

2. Find the density, mass per unit volume — $\rho = (9.3 \times 10^{-26} \text{ kg})/(6.6 \times 10^{-43} \text{ m}^3) = 1.4 \times 10^{17} \text{ kg/m}^3$

(*b*) 1. Find the volume of the earth of density ρ — $V = (5.98 \times 10^{24} \text{ kg})/(1.4 \times 10^{17} \text{ kg/m}^3) = 4.2 \times 10^7 \text{ m}^3$

2. Find the radius using $V = (4/3)\pi r^3$ — $r = (3V/4\pi)^{1/3} = [3 \times (4.2 \times 10^7 \text{ m}^3)/(4\pi)]^{1/3} = 216 \text{ m}$

53* ·· Evaluate the following expressions. (*a*) $(5.6 \times 10^{-5})(0.0000075)/(2.4 \times 10^{-12})$;
(*b*) $(14.2)(6.4 \times 10^7)(8.2 \times 10^{-9}) - 4.06$; (*c*) $(6.1 \times 10^{-6})^2(3.6 \times 10^4)^3/(3.6 \times 10^{-11})^{1/2}$;
(*d*) $(0.000064)^{1/3}/[(12.8 \times 10^{-3})(490 \times 10^{-1})^{1/2}]$.

(*a*) $(5.6 \times 10^{-5})(7.5 \times 10^{-6})/(2.4 \times 10^{-12}) = 1.8 \times 10^2$ to two significant figures.

(*b*) $(14.2)(6.4 \times 10^7)(8.2 \times 10^{-9}) - 4.06 = 7.45 - 4.06 = 3.4$ to two significant figures.

(*c*) $(6.1 \times 10^{-6})^2(3.6 \times 10^4)^3/(3.6 \times 10^{-11})^{1/2} = 2.9 \times 10^8$ to two significant figures.

(*d*) $(6.4 \times 10^{-5})^{1/3}/[(12.8 \times 10^{-3})(49.0)^{1/2}] = 0.45$ to two significant figures.

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54 ·· The astronomical unit is defined in terms of the distance from the earth to the sun, namely 1.496×10^{11} m. The parsec is the radial length that one astronomical unit of arc length subtends at an angle of 1 s. The light-year is the distance that light travels in one year. (*a*) How many parsecs are there in one astronomical unit? (*b*) How many meters are in a parsec? (*c*) How many meters in a light-year? (*d*) How many astronomical units in a light-year? (*e*) How many light-years in a parsec?

Note: If S is the arc length and R the radius, then $\theta = S/R$, where θ is in radians.

(*a*) 1. Express 1 second in radian measure (see Problem 27) — $(1 \text{ s})(1 \text{ min}/60 \text{ s})(1 \text{ deg}/60 \text{ min})(2\pi \text{ rad}/360 \text{ deg}) = 4.85 \times 10^{-6} \text{ rad}$

2. Use $\theta = S/R$ and solve for R — $R = (1 \text{ parsec})(4.85 \times 10^{-6} \text{ rad}) = 4.85 \times 10^{-6} \text{ parsec}$

(*b*) From $\theta = S/R$, $R = S/\theta$ — $R = (1.496 \times 10^{11} \text{ m})/(4.85 \times 10^{-6} \text{ rad}) = 3.08 \times 10^{16} \text{ m}$

(*c*) Speed of light $c = 3.00 \times 10^8$ m/s; $D = ct$ — $1 \text{ l-y} = (3 \times 10^8 \text{ m/s})(3.156 \times 10^7 \text{ s/yr}) = 9.47 \times 10^{15} \text{ m}$

(*d*) Use definition of 1 AU and part (*c*) — $1 \text{ l-y} = (9.47 \times 10^{15} \text{ m})(1 \text{ AU}/1.496 \times 10^{11} \text{ m}) = 6.33 \times 10^4 \text{ AU}$

(*e*) Use parts (*b*) and (*c*) — $1 \text{ parsec} = (3.08 \times 10^{16} \text{ m})(1 \text{ l-y}/9.47 \times 10^{15} \text{ m}) = 3.25 \text{ light-years}$

55 ·· If the average density of the universe is at least 6×10^{-27} kg/m^3, then the universe will eventually stop expanding and begin contracting. (*a*) How many electrons are needed in a cubic meter to produce the critical density? (*b*) How many protons per cubic meter would produce the critical density? ($m_e = 9.11 \times 10^{-31}$ kg; $m_p = 1.67 \times 10^{-27}$ kg)

(*a*) $N_e/\text{m}^3 = (6 \times 10^{-27}\text{ kg})(1\text{ electron}/9.11 \times 10^{-31}\text{ kg}) = 6.6 \times 10^3$ electrons/m^3.

(*b*) $N_p/\text{m}^3 = (N_e/\text{m}^3)(m_e/m_p) = (6.6 \times 10^3\text{ electrons/m}^3)(9.11 \times 10^{-31}\text{ kg/electron})/(1.67 \times 10^{-27}\text{ kg/proton})$
$= 3.6$ protons/m^3.

56 ·· Observational estimates of the density of the universe yield an average of about 2×10^{-28} kg/m^3. (*a*) If a 100-kg football player had this mass uniformly spread out in a sphere to match the estimate for the average mass density of the universe, what would be the radius of the sphere? (*b*) Compare this radius with the earth–moon distance of 3.82×10^8 m.

(*a*) 1. Find the volume of a 100-kg mass — $V = M/\rho = (100\text{ kg})/(2 \times 10^{-28}\text{ kg/m}^3) = 5 \times 10^{29}$ m

2. Use $V = (4/3)\pi R^3$ and solve for R — $R = (3V/4\pi)^{1/3} = (1.5 \times 10^{30}\text{ m}^3/4\pi)^{1/3} = 5 \times 10^9$ m

(*b*) Divide R by the earth–moon distance — $R = (5 \times 10^9\text{ m})/(3.82 \times 10^8\text{ m}) = 13$ E–M distanc

57* ·· Beer and soft drinks are sold in aluminum cans. The mass of a typical can is about 0.018 kg. (*a*) Estimate the number of aluminum cans used in the United States in one year. (*b*) Estimate the total mass of aluminum in a year's consumption from these cans. (*c*) If aluminum returns \$1/kg at a recycling center, how much is a year's accumulation of aluminum cans worth?

(*a*) The population of the U.S. is about 3×10^8 persons. Assume 1 can per person per day. In one year the total number of cans used is $(3 \times 10^8\text{ persons})(1\text{ can/person-day})(365\text{ days/y}) = 1 \times 10^{11}$ cans/y.

(*b*) Total mass of aluminum per year $= (1 \times 10^{11}\text{ cans/y})(1.8 \times 10^{-2}\text{ kg/can}) = 2 \times 10^9$ kg/y.

(*c*) At \$1/kg this amounts to \$2 billion.

58 ·· An aluminum rod is 8.00024 m long at 20.00°C. If the rod's temperature increases, it expands such that it lengthens by 0.0024% per degree temperature rise. Determine the rod's length at 28.00°C and at 31.45°C.

1. Find a relation between L_T, L_{20}, and T. Note that the fractional change is $0.0024 \times \Delta T$. — $L_T = L_{20}[1 + (2.4 \times 10^{-5})(T - 20)]$, where T is in °C and L_{20} and L_T are the lengths at 20°C and temperature T

2. Solve for $L_{28.00}$; keep result to 6 sig. figs. — $L_{28.00} = (8.00024\text{ m})[1 + (2.4\times10^{-5})(8)] = 8.0017$

3. Solve for $L_{31.45}$; keep result to 6 sig.figs. — $L_{31.45} = (8.00024\text{ m})[(1 + (2.4\times10^{-5})(11.45)]$
$= 8.0024$ m

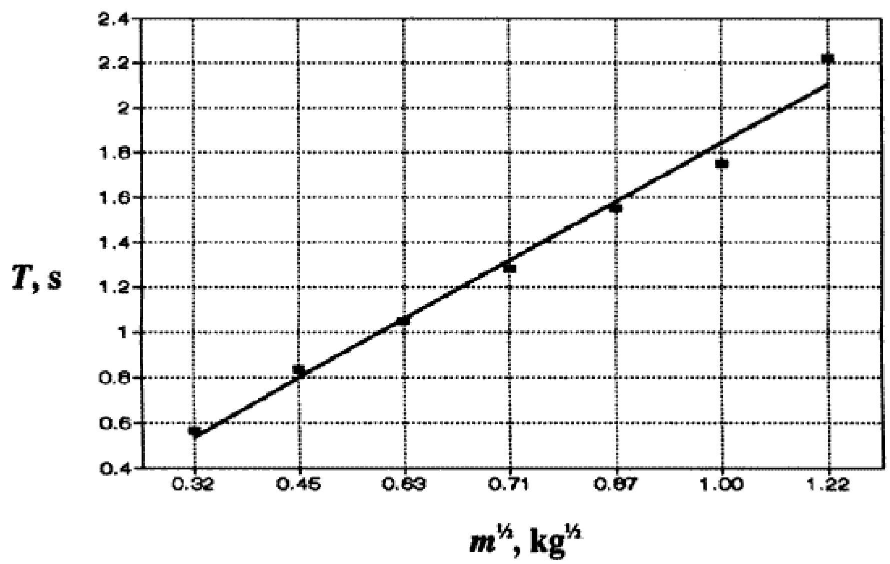
59 ··· The table below gives experimental results for a measurement of the period of motion T of an object of mass

m suspended on a spring versus the mass of the object. These data are consistent with a simple equation expressing T as a function of m of the form $T = Cm^n$, where C and n are constants and n is not necessarily an integer. (*a*) Find n and C. (There are several ways to do this. One is to guess the value of n and check by plotting T versus m^n on graph paper. If your guess is right, the plot will be a straight line. Another is to plot $\log T$ versus $\log m$. The slope of the straight line on this plot is n.) (*b*) Which data points deviate the most from a straight-line plot of T versus m^n?

Mass *m*, kg	0.10	0.20	0.40	0.50	0.75	1.00	1.50
Period *T*, s	0.56	0.83	1.05	1.28	1.55	1.75	2.22

(*a*) We will use a "judicious" guessing procedure. Note that as m increases from 0.1 kg to 1.0 kg, i.e., by a factor of 10, T increases from 0.56 to 1.75, i.e., by a factor of $3.13 \approx \sqrt{10}$. This suggests that we should try $T = Cm^{1/2}$.

A plot of T versus $m^{1/2}$ is shown.



To find the constant C we use the point m = 0.40 kg, T = 1.05 s; $C = (1.05\text{ s})/(0.40\text{ kg})^{1/2} = 1.66$ s/kg$^{1/2}$.

(b) From the plot we see that the data points m = 1.00 kg, T = 1.75 s, and m = 1.50 kg, T = 2.22 s deviate most
from the straight-line plot.

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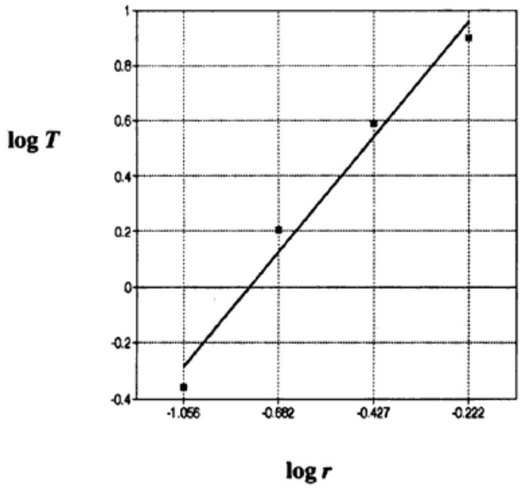
60 ··· The table below gives the period T and orbit radius r for the motions of four satellites orbiting a dense, heavy asteroid. (*a*) These data can be fitted by the formula $T = Cr^n$. Find C and n. (*b*) A fifth satellite is discovered to have a period of 6.20 y. Find the radius for the orbit of this satellite, which fits the same formula.

Period *T*, y	0.441.61	3.88	7.89	
Radius *r*, Gm	0.088	0.208	0.374	0.600

(*a*) We shall plot $\log T$ versus $\log r$; the slope of the best-fit line determines the exponent n.



(a) The slope of the best-fit straight line is 1.5; $n = 3/2$. To find C we use the point $r = 0.374$ Gm, $T = 3.88$ yr.
This gives $C = (3.88\text{ yr})/(0.374\text{ Gm})^{3/2} = 17\text{ yr/(Gm)}^{3/2}$.

(*b*) We use $r = (T/C)^{2/3}$; $r = [(6.20\text{ yr})/(17\text{ yr/(Gm)})]^{2/3} = 0.510$ Gm.

61* ··· The period T of a simple pendulum depends on the length L of the pendulum and the acceleration of gravity g (dimensions L/T^2). (*a*) Find a simple combination of L and g which has the dimensions of time. (*b*) Check the dependence of the period T on the length L by measuring the period (time for a complete swing back and forth) of a pendulum for two different values of L. (*c*) The correct formula relating T to L and g involves a constant which is a multiple of π, and cannot be obtained by the dimensional analysis of part (*a*). It can be found by experiment as in (*b*) if g is known. Using the value $g = 9.81\text{ m/s}^2$ and your experimental results from (*b*), find the formula relating T to L and g.

(*a*) 1. Write $T = CL^ag^b$ and express dimensionally $\quad T = L^a(L/T^2)^b = L^{a+b}T^{-2b}$.

2. Solve for a and b $\quad -2b = 1$, $b = -1/2$; $a + b = 0$, $a = 1/2$.

3. Write the expression for T $\quad T = C\sqrt{L/g}$

(*b*) Check by using pendulums of lengths 1 m and 0.5 m; the periods should be about 2 s and 1.4 s.

(b) Using $L = 1$ m, $T = 2$ s, $g = 9.81\text{ m/s}^2$, $C = (2.0\text{ s})/\sqrt{1.0\text{ m}/9.81\text{ m/s}^2} = 6.26 = 2\pi$. $T = 2\pi\sqrt{L/g}$.

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62 ··· The weight of the earth's atmosphere pushes down on the surface of the earth with a force of 14.7 lbs for each square inch of earth's surface. What is the weight in pounds of the earth's atmosphere? (The radius of the earth is about 6370 km.)

1. Find the total surface area of the earth	$A = 4\pi r^2 = 4\pi(6.37 \times 10^6\ \text{m})^2 = 5.1 \times 10^{14}\ \text{m}^2$
2. Express A in square inches	$A = (5.1 \times 10^{14}\ \text{m}^2)(10^4\ \text{cm}^2/\text{m}^2)(1\ \text{in}^2/2.54^2\ \text{in}^2)$ $= 7.9 \times 10^{17}\ \text{in}^2$
3. Multiply the area A by 14.7 lb/in^2	$W = (14.7\ \text{lbs/in}^2)(7.9 \times 10^{17}\ \text{in}^2) = 1.16 \times 10^{19}$ lbs

63 ••• Each binary digit is termed a bit. A series of bits grouped together is called a word. An eight-bit word is called a byte. Suppose a computer hard disk has a capacity of 2 gigabytes. (*a*) How many bits can be stored on
the disk? (*b*) Estimate the number of typical books that can be stored on the disk.

(*a*) Number of bits = N_{bytes}(number of bits/byte)	$N_{\text{bits}} = (2 \times 10^9$ bytes)(8 bits/byte) $= 1.6 \times 10^{10}$ bits
(*b*) 1. Estimate the number of bits required for the alphabet	A bit is 0 or 1. So $2^5 = 32$ bits can be used to represent the alphabet of 26 letters. We need 4 bytes per letter.
2. Assume an average of 8 letters/word	Need 8×4 bytes/word = 32 bytes/word
3. Assume 10 words/line and 60 lines/page	600 words/page = 600×32 bytes/page $= 1.92 \times 10^4$ bytes/page
4. Assume book length of 300 pages	$(1.92 \times 10^4$ bytes/page)(300 pages) $= 5.8 \times 10^6$ bytes
5. $N_{\text{books}} = (2 \times 10^9$ bytes/disk)/($N_{\text{bytes/book}}$)	$N_{\text{books}} = (2 \times 10^9$ bytes)/(5.8×10^6 bytes/book) $= 350$ books